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## SIZE RELATIONSHIPS BETWEEN CONJUGANTS AND NON-CONJUGANTS IN BLEPHARISMA UNDULANS.

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It has been shown by Pearl ('07) that in *Paramæcium* cultures the conjugants differ from the non-conjugants in size and variability and that a correlation in size occurs between the two members of conjugating pairs. He has shown by statistical methods (1) that the conjugants are less variable in size than the non-conjugants, (2) that the conjugants show a smaller mean size than the non-conjugants, and (3) that a marked correlation in size exists between the members of the conjugating pairs, the smaller uniting with the smaller and the larger with the larger.

Jennings ('11) took up the problem of size relationships in *Paramæcium* going into discussion of the reasons for the conditions found, which he based on very careful observations of the conditions existing in his cultures. After careful measurement of a great many individuals he confirmed the results obtained by Pearl, *i. e.*, (1) that the conjugants are smaller than the non-conjugating population of a culture; (2) that they are less variable than the non-conjugants; and (3) that there is a marked correlation in size between the members of the pairs, so that on the whole larger individuals are found mated with larger, smaller individuals with smaller. It was with the idea of investigating the size relationships in another related form, that the present work on *Blepharisma undulans* was taken up. It will be possible here to give the facts of the size relationships only as they were found in material already mounted.

The individuals under consideration are from a pure-line culture isolated at Woods Hole on July 20, 1911, by Professor Calkins. The six lots with which I shall deal were killed by him at various times during October, 1911, by means of sublimate acetic, stained with Hoyer's picrocarmine, and mounted permanently in Canada balsam.

In measuring the individuals, a Leitz projectoscope was used

to throw a projection of each one upon the drawing table below. A permanent record of each one was obtained by drawing a line perpendicular to the long axis at each end. The figures given are the measurements of the projections rather than of the individuals themselves and are 192 times the actual size. Thus in the table:

	Longest, Mm.	Shortest, Mm.	Average, Mm.
Non-conjugants.....	42.5	13.5	27.67
Conjugants.....	30.0	15.5	20.12

the size of the projection rather than the actual size is given. Translated, these figures would be:

	Longest, $\mu$ .	Shortest, $\mu$ .	Average, $\mu$ .
Non-conjugants.....	221.35	70.31	144.11
Conjugants.....	156.25	78.12	104.79

But since it is the relative length rather than the absolute length which is of importance in this case, it has not seemed necessary to divide all the numbers given below by 192, and the figures denoting the size of the projection stand in the statistics which follow. For the sake of overcoming any element of personal error which may have entered into the measurements, all measurements falling half way between one mm. mark and the next are considered with those .5 mm. larger.

The results obtained by careful measurements of six lots of *Blepharisma undulans* are in accord with the results obtained by Pearl ('07) and Jennings ('11), i. e., in *Blepharisma undulans* (1) the mean length of the conjugants is less than the mean length of the non-conjugants, (2) the variation in length is much less among the conjugants than among the non-conjugants, and (3) the correlation in size between the two members of a pair is distinctly marked, the larger mating with the larger and the smaller with the smaller. To take up first the difference in length between the conjugants and non-conjugants: Table I. shows that in all six lots the mean length of the conjugants is less than that of the non-conjugants.<sup>1</sup> Plate I. shows that the mean length of the

<sup>1</sup> The ordinates indicate the size of the individuals while the abscissas indicate the number of individuals; thus the position of the column indicates the size while the height of the column indicates the number of individuals.

conjugants of lot 1 is 21 units and that the number of individuals increases rather rapidly from the extremes, 17 and 30, toward the mean, 21; also that the mean length of the non-conjugants is 29 and that the number of individuals increases slowly at first and then more rapidly from the extremes 18 and 40 to the mean 29. The average lengths of the conjugants and non-conjugants is in accord with the mean length, being greater in the case of the non-conjugants and less in the case of the conjugants (Table I.).

Plate II. shows that the mean length of the conjugants of lot 2 is less than the mean length of the non-conjugants, the former being 22 and the latter 32. The number of individuals of the conjugants and non-conjugants increases from the extremes 18.5 and 28 in the case of the former, and 18.5 and 42.5 in the case of the latter, to the means 22 and 32. That the increase from extremes to means is much more gradual in lot 2 than in lot 1, is due to the fact that there are over twice as many individuals in lot 1 as in lot 2. The average length of the conjugants is less than that of the non-conjugants, as in lot 1, being 23.46 and 33.88 respectively.

TABLE I.

SIZE RELATIONS IN CONJUGANTS AND NON-CONJUGANTS.

Series.	I.	II.	III.	IV.	V.	VI.	Total.
No.	{ N. 390 C. 160	{ 148 30	{ 551 292	{ 47 20	{ 47 20	{ 198 28	{ 1,381 550
Total length	{ N. 10,898 C. 3,426.5	{ 5,014.5 704	{ 13,744 6,057.5	{ 1,253 415.5	{ 1,112.5 431	{ 6,195 638.5	{ 38,217 11,673
Average	{ N. 27.9 C. 21.41	{ 33.88 23.46	{ 24.94 20.06	{ 26.65 20.77	{ 23.67 21.55	{ 31.28 22.80	{ 27.67 20.12
Longest	{ N. 40 C. 30	{ 42.5 28	{ 33.5 27	{ 34.5 25	{ 34 25.5	{ 40 27.5	{ 42.5 30
Shortest	{ N. 18 C. 16.5	{ 18.5 18.5	{ 13.5 16.5	{ 18 15.5	{ 18.5 18.5	{ 16.5 19	{ 13.5 15.5
Variations	{ N. 22 C. 13.5	{ 24 9.5	{ 20 10.5	{ 16.5 9.5	{ 16.5 7	{ 23.5 8.5	{ 29 14.5
Mean	{ N. 29 C. 21	{ 32 22	{ 25 21	{ 29 20	{ 27 22	{ 32 23	{ 27.5 21
Median	{ N. 29 C. 23.25	{ 30.5 23.25	{ 23.25 21.25	{ 26.25 20.25	{ 26.75 22	{ 28.25 23.25	{ 28 22.75

N. indicates non-conjugants.

C. indicates conjugants.

Lot 3, Plate III., shows the same relative conditions as to mean and average length of conjugants and non-conjugants, the mean

length of the former being 21, and that of the latter 25. The averages are 20.06 and 24.94 respectively. The rapid increase in the number of individuals from the extremes 16.5 and 27, and 13.5 and 33.5 respectively is due to the larger number of individuals present in lot 3.

Lot 4, Plate IV., shows the same relative conditions as those found in the other lots, the mean lengths of conjugants and non-conjugants being 20 and 29 respectively, while the average lengths are 20.77 and 26.65. The small number of individuals occurring in lot 4 accounts for the lowness of the columns.

Lot 5, Plate IV., is like lot 4 in the number of individuals and in the shortness of the columns. There is greater irregularity of outline in lot 5 than in any other of the six lots, but the mean length of conjugants and non-conjugants is in accord with the mean length of the other lots, the former being 22 and the latter 27.

Lot 6, Plate IV., agrees with the rest in having the mean and average lengths of the conjugants smaller than those of the non-conjugants, the means being 23 and 32, and the averages 22.80 and 31.28 respectively. Thus in every one of the six lots, the mean and average have been less in the case of the conjugants than in that of the non-conjugants, the difference being from 5 to 10 units in the case of the means, and from 2 to 10 in the case of the averages. From all this we should expect to find that the mean and average of the total number of conjugants are less than those of the total number of non-conjugants. This is the case, the mean for the total number of conjugants being 21 and the average 20.12; and the mean for the total number of non-conjugants being 27 and 28 (or 27.5) and the average 27.67.

One interesting fact appears in Table I. and Plates I. to IV., which is shown best in Plates IV. and V., *i. e.*, the population including conjugants and non-conjugants shifts toward the left or right in the various lots. Plate V. shows this for the non-conjugants of lots 1, 2, and 3, the means being 29, 32, and 25, and the extremes 18 and 40, 19 and 43, and 14 and 34 respectively. The means of the non-conjugants of lots 4, 5, and 6, Plate IV., are 29, 27, and 32 respectively while the extremes are 18 and 35, 19 and 34, and 17 and 40. The conjugating populations do not show

this so well since they vary less than the non-conjugating populations.

This brings us to the consideration of the second of the three problems, *i. e.*, the variation of conjugants and non-conjugants. Table I. shows very clearly that the variation between the extremes in the case of the conjugants is much less than that in the case of the non-conjugants, being in the six lots:

13.5	9.5	10.5	9.5	7	8.5	in the former,
22	24	20	16.5	16.5	23.5	in the latter,

the variation ranging from nearly two times to nearly three times as great in the case of the non-conjugants. It is probable that some of the shortest non-conjugants are ex-conjugants, which would however not change the general results very appreciably.

Finally the third problem, as to coördination in size of the members of the same pair, appears. By plotting a graph using the length of the shorter of the two individuals as abscissa, and the longer as ordinate, the number of pairs of each combination which appeared was obtained. Then by adding diagonally, I obtained the number of pairs in which the individuals varied less than .5 mm. (or 2.2 microns, actual measurement), which varied .5 mm., 1 mm., 1.5 mm., etc., the following table resulting:

TABLE II.

CORRELATION IN SIZE OF MEMBERS OF CONJUGATING PAIRS.

	Pairs.
Both members equal in length.....	35
One member shorter by 0.5 mm.....	57
One member shorter by 1.0 mm.....	62
One member shorter by 1.5 mm.....	50
One member shorter by 2.0 mm.....	34
One member shorter by 2.5 mm.....	17
One member shorter by 3.0 mm.....	9
One member shorter by 3.5 mm.....	8
One member shorter by 4.0 mm.....	2
One member shorter by 4.5 mm.....	2
One member shorter by 5.0 mm.....	2
One member shorter by 5.5 mm.....	1

No two members of the same pair show a greater variation than 5.5 mm., though conjugating individuals of different pairs show as great a variation as 14.5 mm.; and out of 279 pairs of con-

jugants only 7 pairs show a greater variation than 3.5 mm. This indicates a very definite correlation of size between the two members of the conjugating pairs.

The same conditions which Pearl ('07) and Jennings ('11) found to exist in *Paramæcium*, then, have been shown to exist in the case of *Blepharisma undulans*, *i. e.*, (1) the mean length of the conjugants is less than that of the non-conjugants, (2) the variation of the conjugants is less than that of the non-conjugants, and (3) there is a definite positive correlation in size between the members of the conjugating pairs, the larger uniting with the larger individuals and the smaller with the smaller.

#### REFERENCES.

**Pearl, R.**

- '07 A Biometrical Study of Conjugation in *Paramæcium*. *Biometrika*, Vol. V., pp. 213-297.

**Jennings, H. S.**

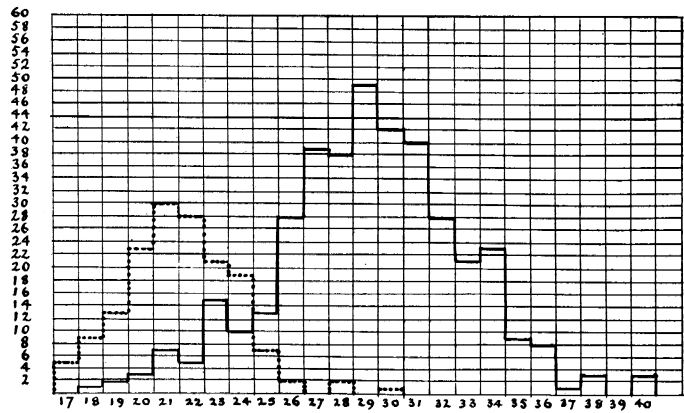
- '11 Assortive Mating, Variability and Inheritance of Size in the Conjugation of *Paramæcium*. *Jour. Exp. Zool.*, Vol. II., No. 1, July, 1911.

## EXPLANATION OF PLATES.

## PLATE I.

Lot 1. *Blepharisma undulans*. Abscissas: number of individuals. Ordinates: size of individuals. — non-conjugates. .... conjugants.

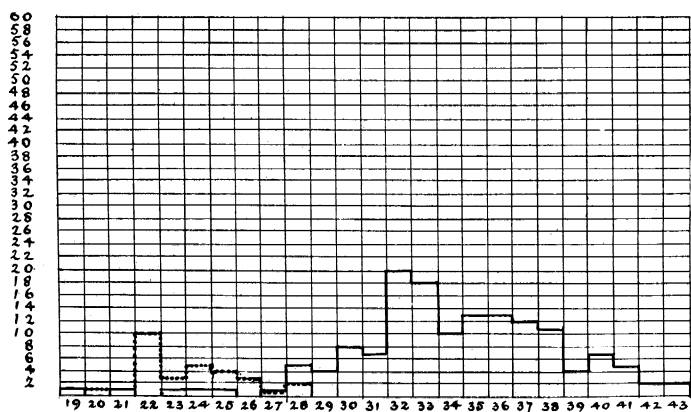




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## PLATE II.

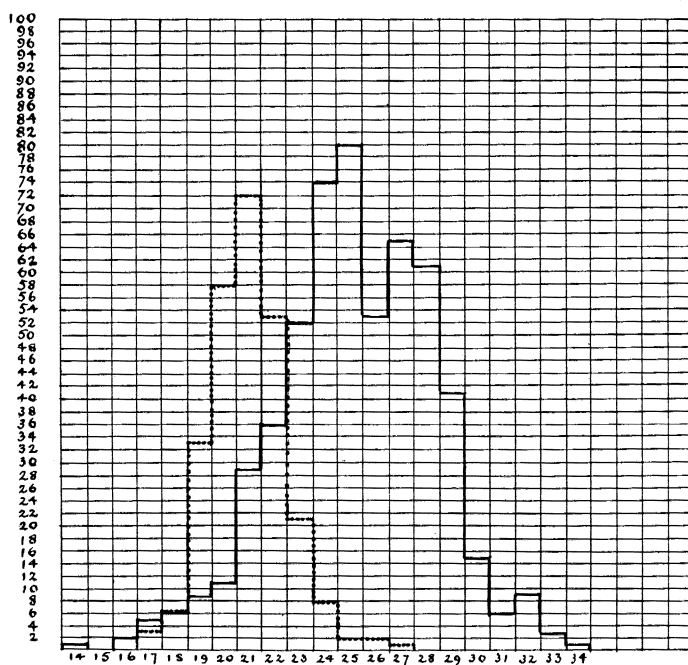
Lot 2. *Blepharisma undulans*. Abscissas: number of individuals. Ordinates: size of individuals. — non-conjugants. .... conjugants.



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## PLATE III.

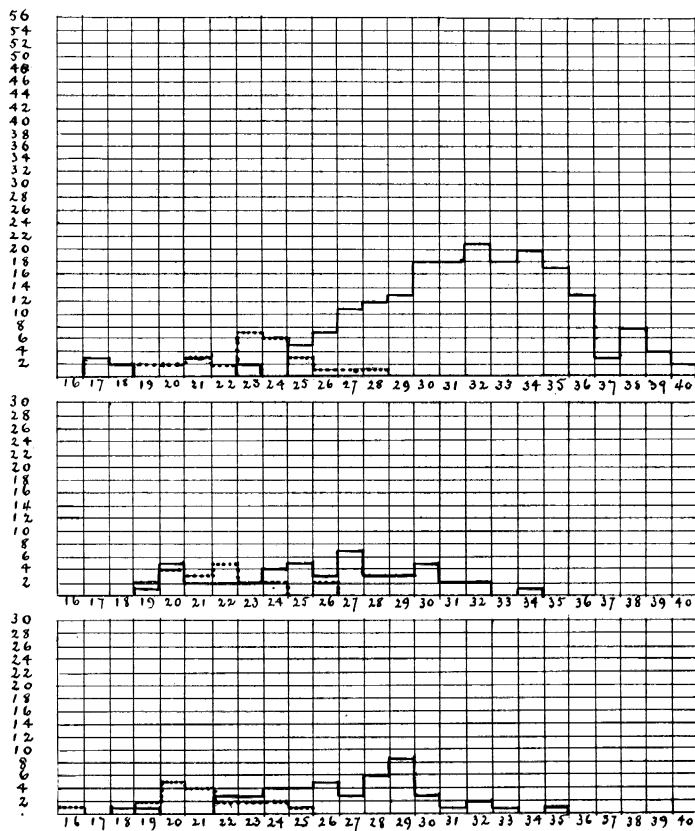
Lot 3. *Blepharisma undulans*. Abscissas: number of individuals. Ordinates: size of individuals. — non-conjugants. .... conjugants.



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## PLATE IV.

Lots 4, 5, 6. *Blepharisma undulans*. Abscissas: number of individuals. Ordinates: size of individuals. — non-conjugants. .... conjugants.

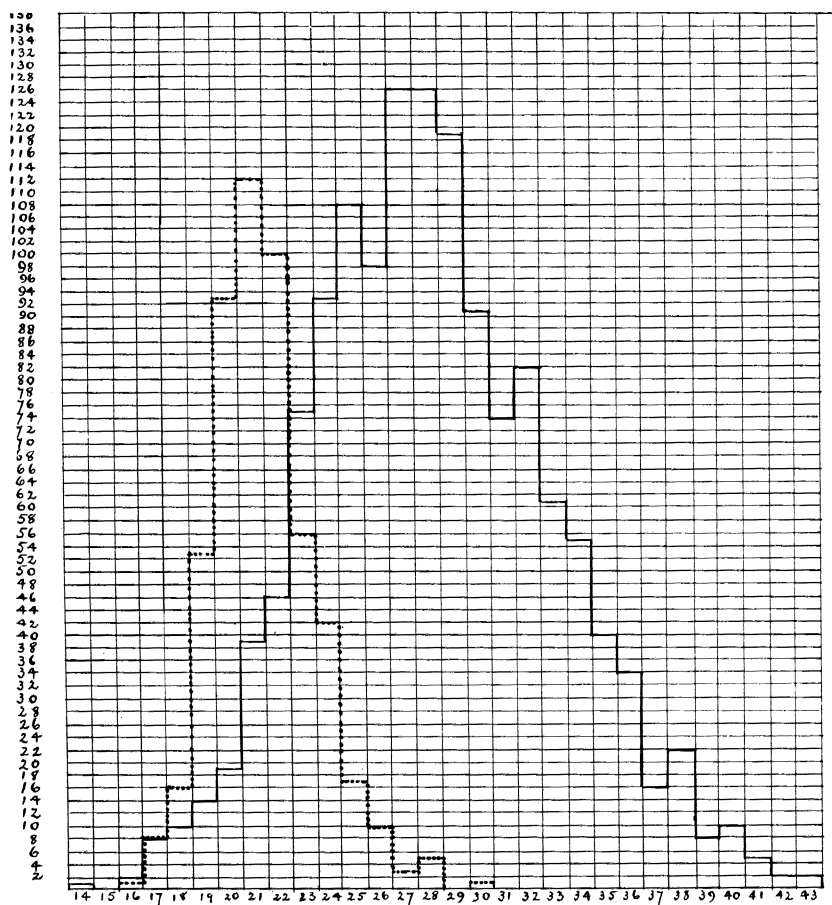


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## PLATE V.

Lot "Total." *Blepharisma undulans*. Abscissas: number of individuals. Ordinates: size of individuals. — non-conjugants. .... conjugants.

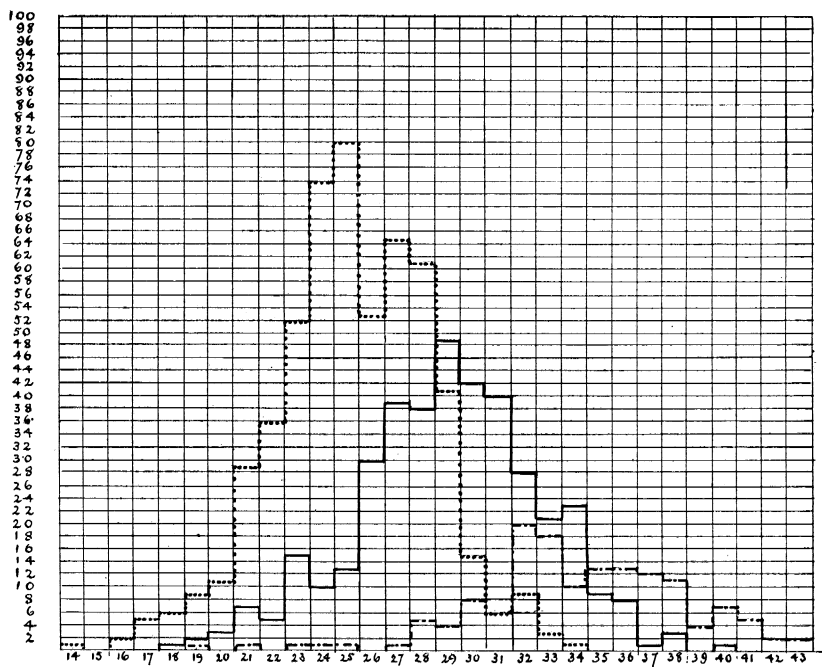




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## PLATE VI.

Lots 1, 2, 3. *Blepharisma undulans*. Abscissas: number of individuals. Ordinates: size of individuals. — Lot 1. .... Lot 2. — · — Lot 3.



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